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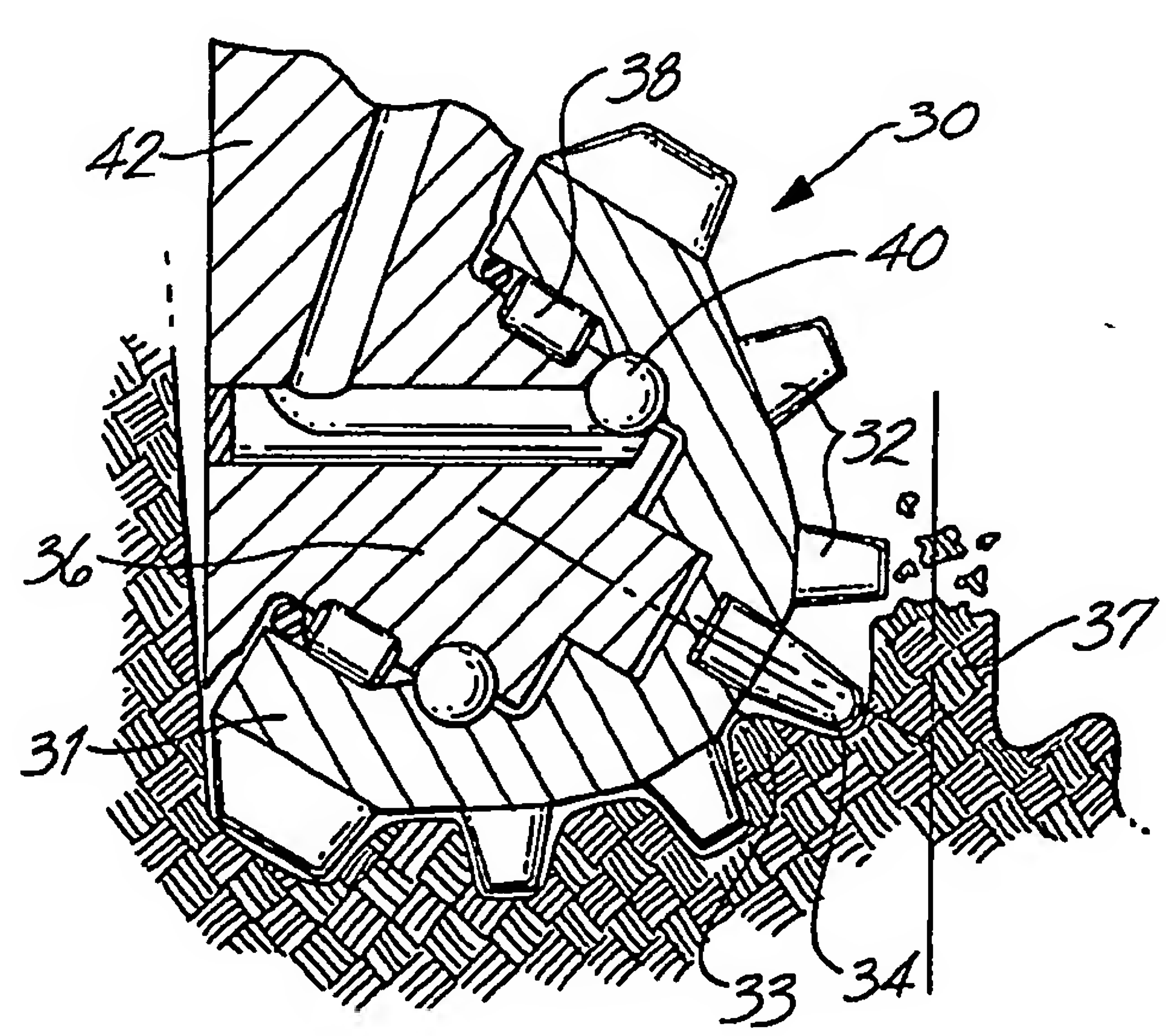
(54) Core cutting rock bit

(57) A roller cone drill bit is disclosed that leaves uncut a formation core 37 having a diameter from 100% to 25% of the bit gage diameter. Cutters in circumferential rows 32 away from the apex of the cones extend a sufficient distance closer to the centerline of the rock bit than the core cutters 34 at the apex of a cone for breaking the central core. The bit is designed to have normal size bearings, cone shell thickness and cutter protrusion to allow the use of standard drilling weights and rotary speeds, thereby achieving a significant increase in drilling rate. When drilling abrasive formations, ultra hard cutting teeth 34 are used in the cone apex to maintain the core diameter.

Fig. 4



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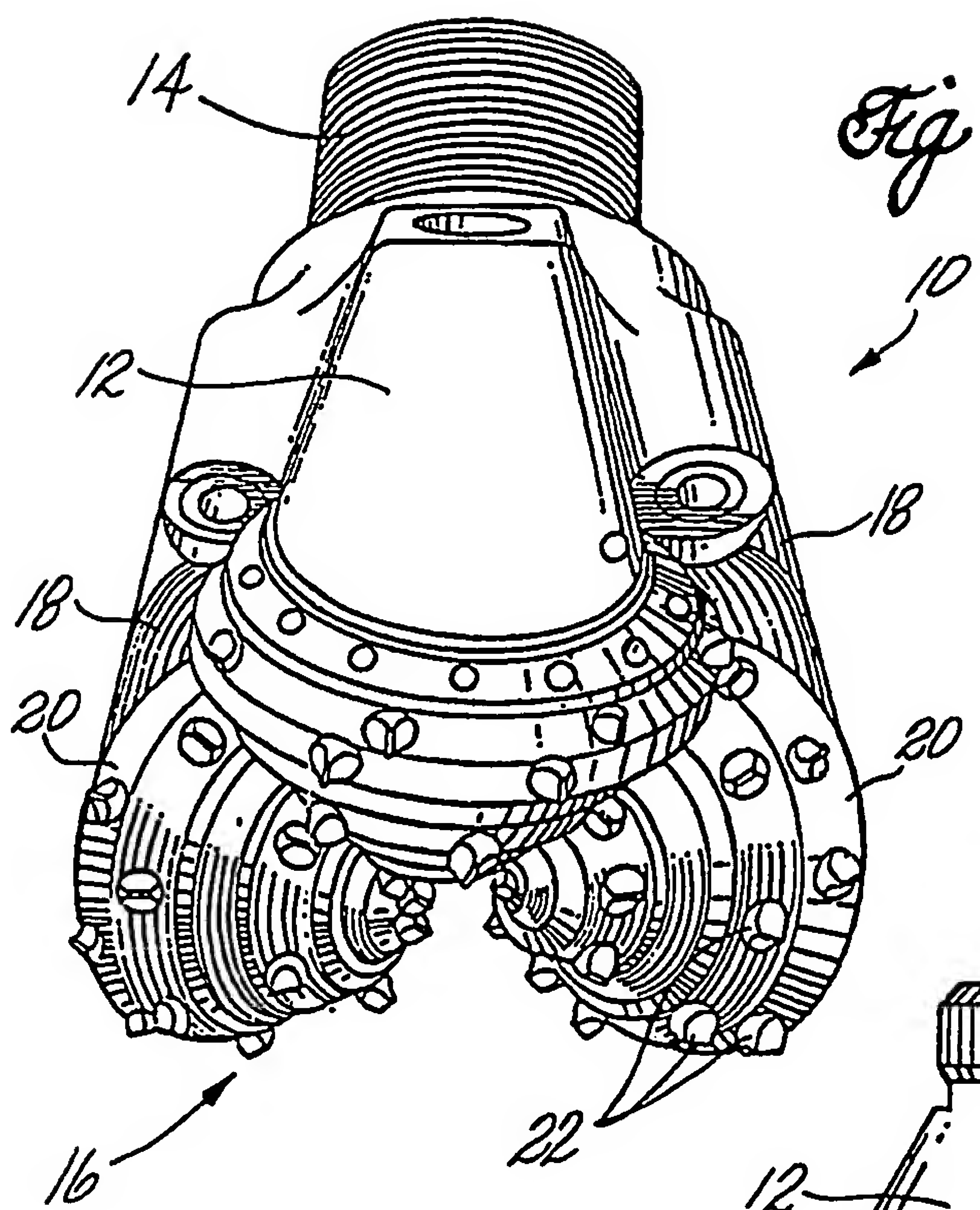
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Fig. 1

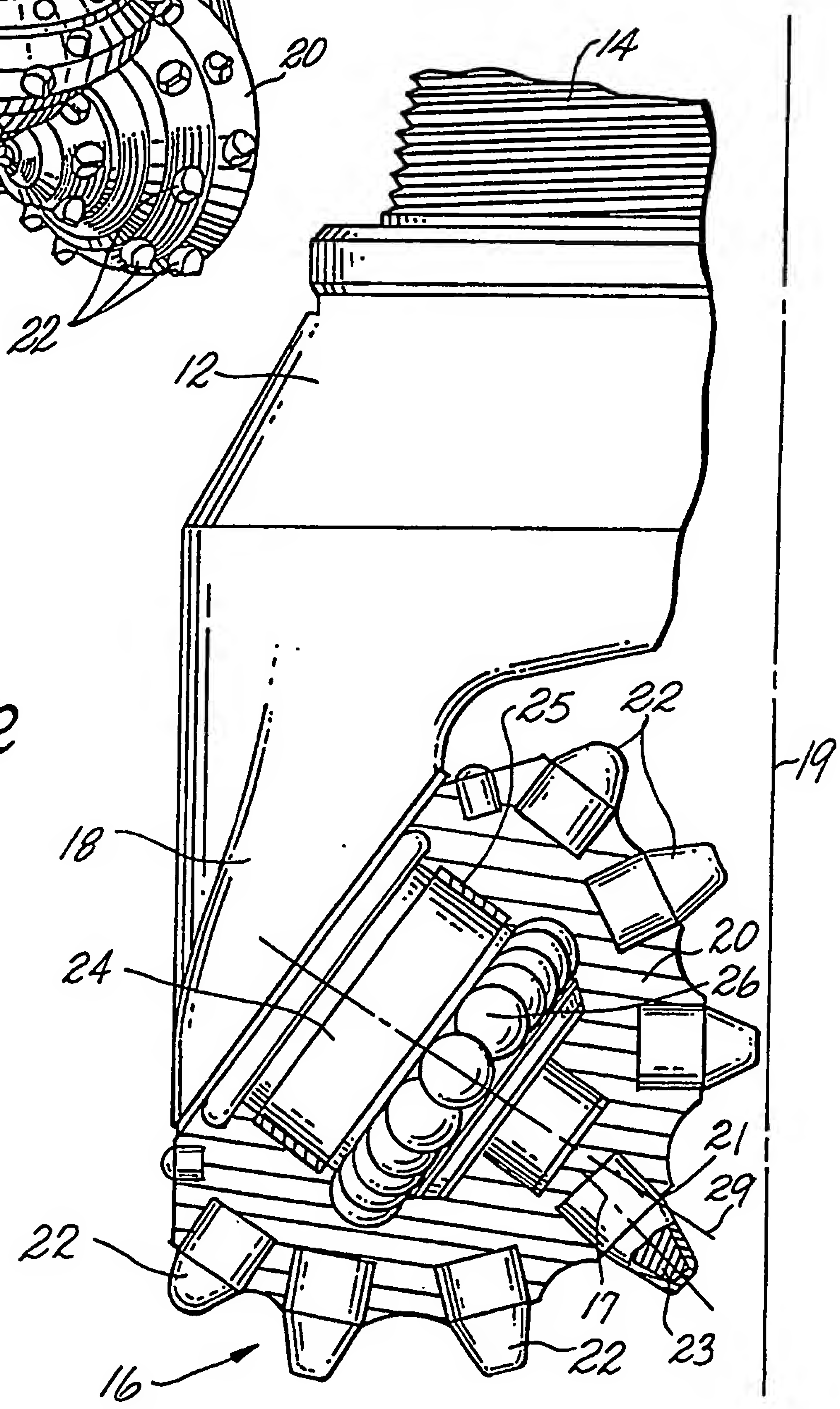
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Fig. 2

Fig. 3

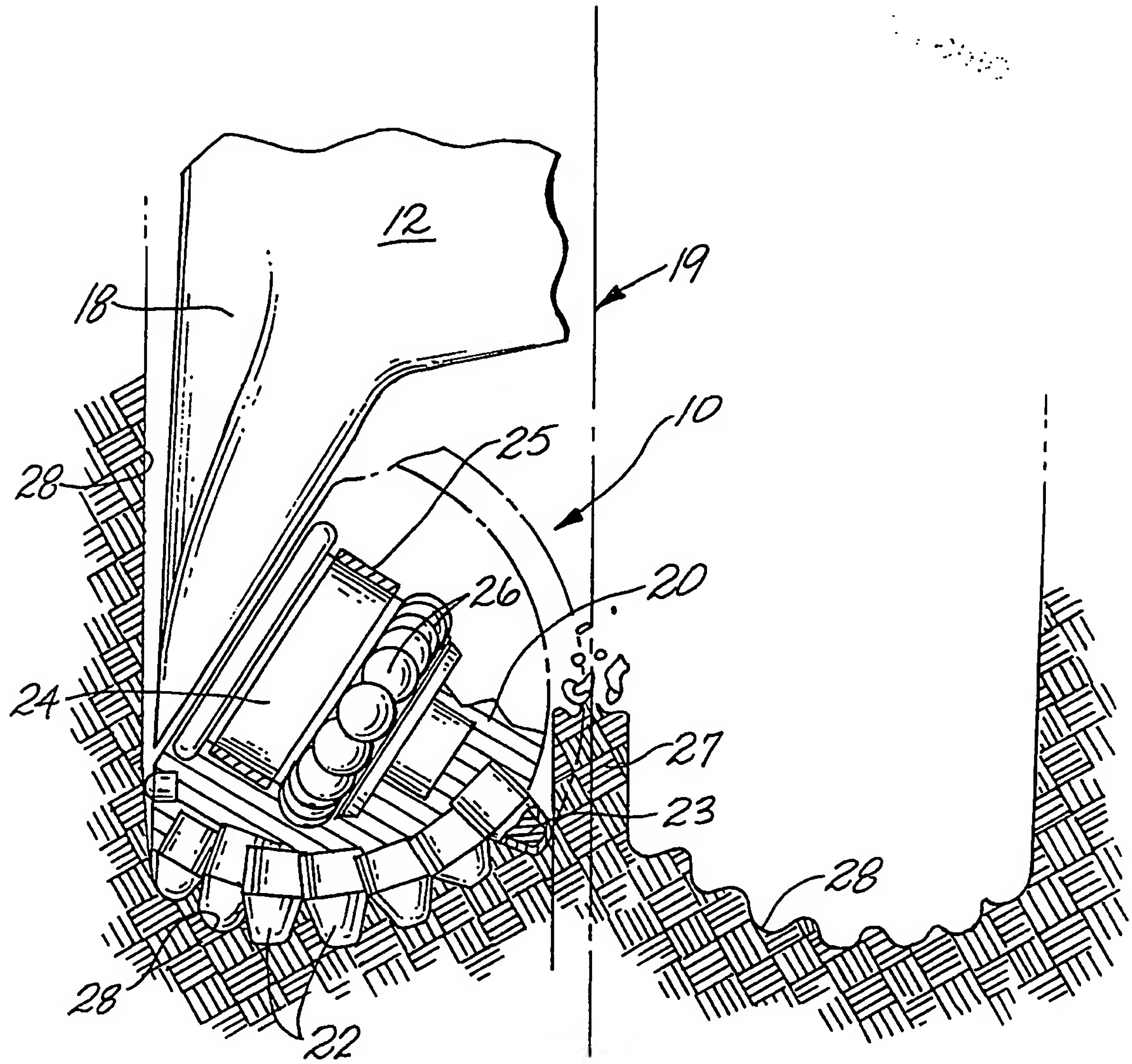

Fig. 4

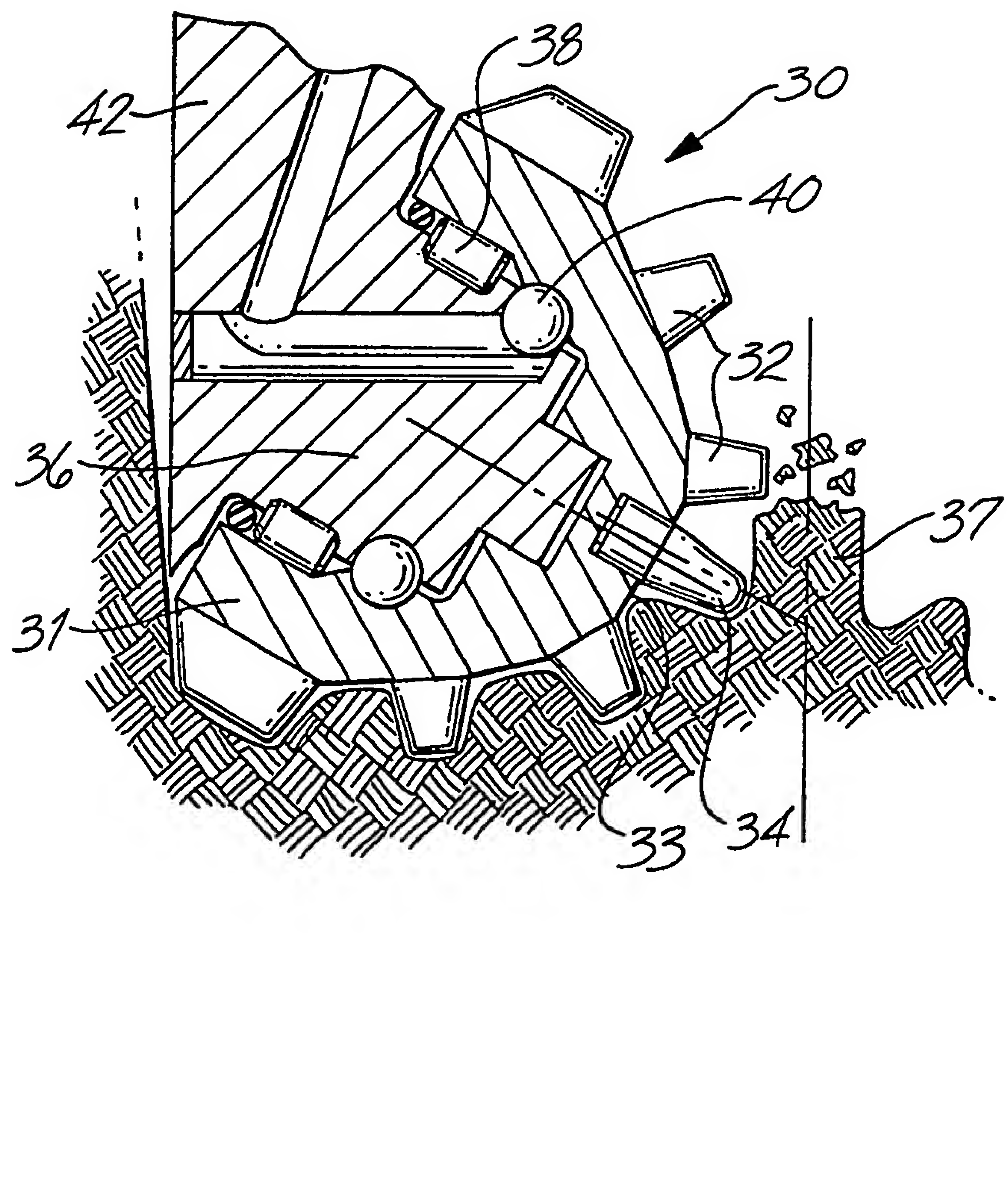

Fig. 5

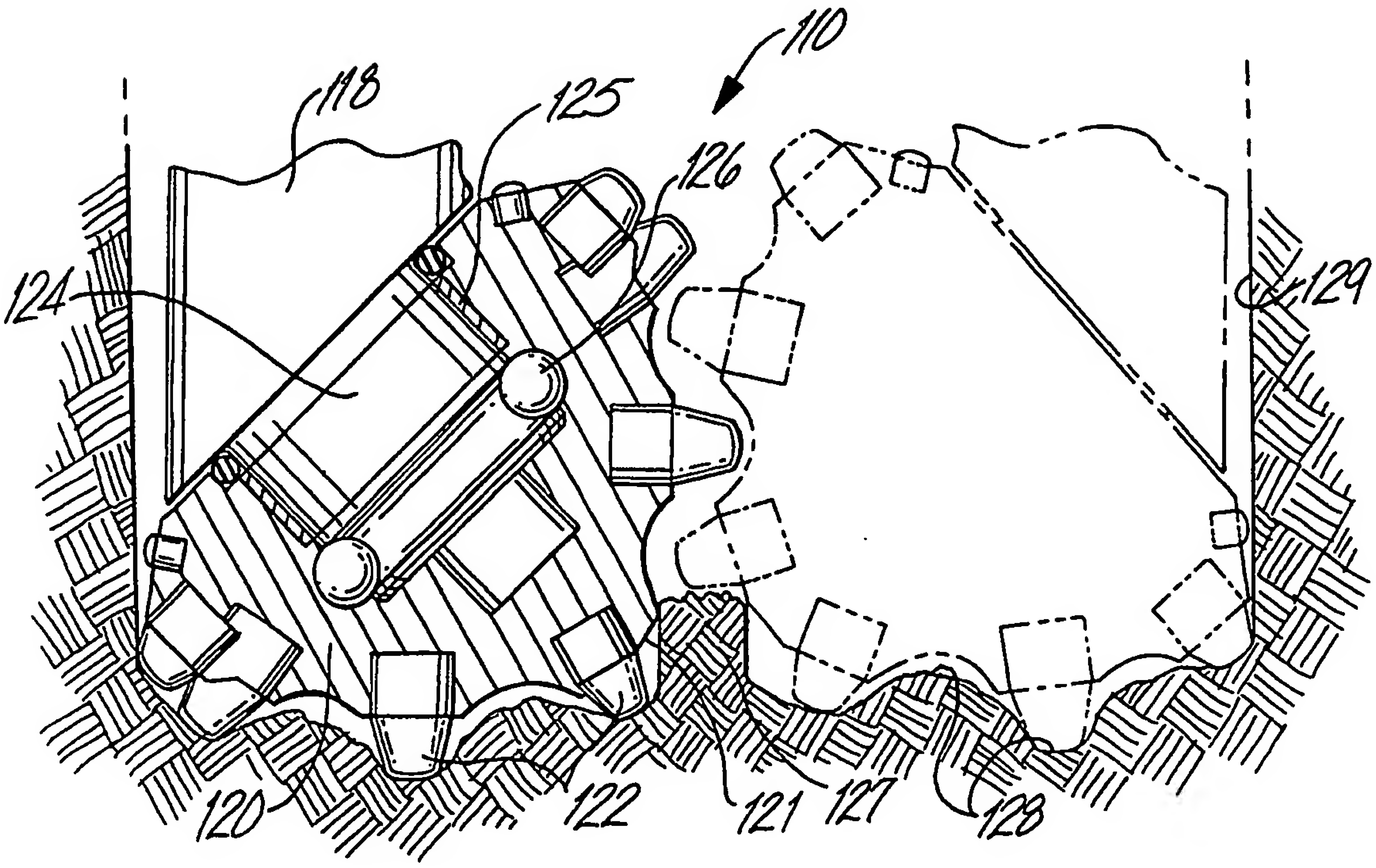
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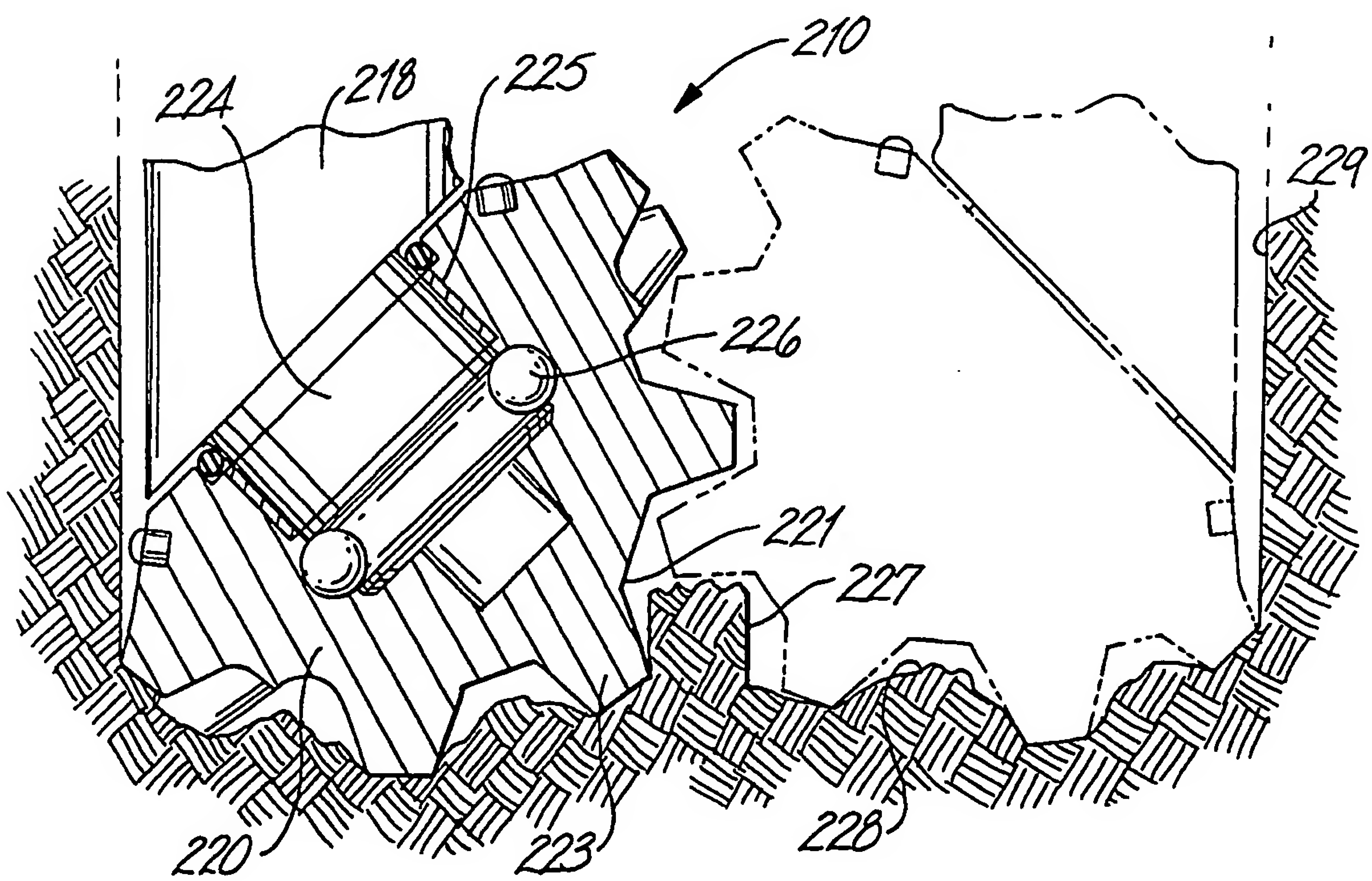
Fig. 6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CORE CUTTING ROCK BIT

The present invention relates generally to earth boring roller cone rock bits. More particularly, this invention relates to roller cone drill bits that leave uncut a significant size core of the formation being drilled to substantially enhance the drilling rate of the bit. The diameter of the core being left is preferably maintained by the use of inserts in the cone apexes made of significantly harder and more wear resistant material than are the main cutting elements on the roller cones.

Roller cone rock bits are used extensively in drilling for petroleum, minerals and geothermal energy. Roller cone bits generally comprise a main bit body which can be attached to a rotary drill string. The bit body normally includes two or three legs which extend downward. Each leg has a journal bearing extending at a downward and inward angle. A roller cone with tungsten carbide inserts (TCI bit), steel teeth (milled tooth bit) or other cutter elements positioned on its outer surface, is rotatably mounted on each journal or roller bearing. During drilling, the rotation of the drill string produces rotation of each roller cone about its bearing, thereby causing the cutter elements to engage and disintegrate the rock.

Because of their aggressive cutting action relatively fast drilling rates are achieved, but very often roller bits designed to drill the entire hole bottom do not drill at acceptable rates.

U.S. Patent No. 2,901,223 describes a "milled-tooth" roller cone drill bit with large steel teeth designed to leave uncut a substantial formation core at the center of the borehole bottom when drilling very soft, deformable strata to enhance the rate of penetration. The core diameter is maintained by the steel teeth at the apex or "spear-point" of each roller cone. The core is broken up

when contacting a centrally and vertically positioned core breaker extending from the bit body. The broken core fragments are flushed out from under the bit by drilling fluid exiting from jet nozzles directed between the cones.

This bit design did not gain much acceptance as all of the steel teeth wore away fairly rapidly. Although the wear of the outer teeth on the cones was not severe enough to stop the drilling process, the wear of the teeth on the cone apexes allowed a core of ever-increasing diameter to form. This design also lacked intermeshing teeth that decreased the bearing size and prevented self-cleaning of teeth that can lead to bit balling. Neither the mechanical action of the core breaker mechanism, nor the jet hydraulic energy were sufficient to the break and flush the enlarged core from under the cutting structure of the bit, thereby stopping the drilling process prematurely. A costly "round trip" of the drill string was then necessary to replace the worn bit.

U.S. Patent No. 3,134,447 shows a tungsten carbide insert type roller bit for drilling fairly hard and abrasive rock formations. This bit type was deliberately designed to leave a very small uncut formation core to alleviate the undercutting of the steel at the apex of the cone with subsequent loss of the carbide inserts. By terminating the cone before it reaches the bit center, a blunter cone can be made that will accommodate many more carbide inserts, thereby protecting the steel of the cone apex from abrading away and ultimately losing inserts. This bit, while useful in drilling a very limited range of very hard and abrasive rocks, does not compete in drilling the major range of sedimentary formations because of very slow drilling rates. The slow drilling rate is directly attributable to the massive concentration of carbide inserts in the apex areas of the roller cones, which produces a very low point loading of the rock by the inserts. This low point loading is generally insufficient to reach the fracture threshold of the rock being drilled.

It is, therefor, desirable to have a new roller cutter drill bit for core cutting which overcomes the inadequacies of the prior art.

Thus, there is provided in practice of this invention, a rotary cone rock bit for drilling earthen formations designed to form a core while drilling a borehole for enhanced bit penetration rates. The bit body has a first threaded pin end, a second cutter end and at least a pair of legs that support roller cutter cones rotatably retained on bearings cantilevered from an end of each leg. Each of the cutter cones contains circumferential rows of individual cutters, either milled

teeth or tungsten carbide inserts. One or more core cutters are provided substantially at an apex of each cone for cutting adjacent to a central core, preferably, to leave a core having a diameter in the range of 10% to 25% of the diameter of the bit. At least a portion of the cutters in the circumferential rows extend a sufficient distance closer to the centerline of the rock bit than the core cutter means at the apex of a cone for breaking the central core.

Preferably, such a core cutter is an insert type cutter that is harder than the cutters in the circumferential rows. For example, when the cutters are milled teeth on the cone, the core cutter may be a cemented tungsten carbide insert. When the cutters in the circumferential rows are themselves tungsten carbide inserts, the core cutter may be a tungsten carbide insert having a surface layer of polycrystalline diamond.

In a preferred embodiment, the foreshortened apexes of the cones are each fitted with at least one insert preferably positioned off-center to each cone axis or angled obliquely for leaving a formation core with a diameter of at least 10% of the bit gage diameter. The cutting inserts on adjacent cones are preferably arranged so that cutters on adjacent cones intermesh with each other for breaking up the core above the bottom of the borehole being drilled.

A roller cone rock bit constructed according to this invention leaves an uncut earthen core of such size that the drilling rate of the bit is significantly increased. The diameter of the core is maintained to the original design dimension throughout the useful life of the main cutting structure teeth or carbide inserts of the bit by use of one or more core trimmer inserts on the roller cone apexes that are harder and more wear resistant than the teeth or inserts of the main cutting structure of the bit. The core is easily broken off at its base on the hole bottom and then broken up into rock chips by the intermediate circumferential rows of teeth or inserts on the rotating cones. The chips are then circulated from under the bit cutting structure by drilling "mud" exiting jet nozzles positioned between the roller cones.

The above-noted features and advantages of the present invention will be more fully understood upon a study of the following description in conjunction with the detailed drawings wherein:

FIGURE 1 is a side view of a three cone tungsten carbide insert drill bit;

FIGURE 2 is a partial cross-section of a leg and roller cone of the bit shown in Figure 1;

FIGURE 3 is a cross-section of a borehole with a tungsten carbide drill bit leaving an uncut formation core;

FIGURE 4 is a partial cross-section of a milled steel tooth drill bit;

FIGURE 5 is a partial cross-section of one tungsten carbide insert cone and a phantom outline of an adjacent cone depicting an uncut formation core; and

FIGURE 6 is a partial cross-section of one milled tooth cone and a phantom outline of an adjacent cone depicting an uncut formation core.

With reference to the side view of FIGURE 1, the drill bit generally designated as 10, comprises a bit body 12 having an open threaded pin end 14 and an opposite cutting end generally designated as 16. Three legs 18 extending downwardly and inwardly have three roller cones 20 rotatably mounted thereon. Tungsten carbide inserts 22 are strategically affixed on cones 20. Conventional fluid nozzles (not shown) are positioned between the cones 20 to direct drilling fluid to the bit cutting end 16 to carry the drill cuttings from the borehole bottom. The nozzles hydraulically communicate with a plenum within the bit body 12 (not shown).

The partial cross-section of FIGURE 2 shows the bit body 12 having a leg 18 extending downward with a bearing journal 24 cantilevered downwardly and inwardly. A cutter cone 20 is rotatably supported on the journal and is retained on the journal by ball bearings 26. A friction bearing 25 supports the down thrust load while drilling. Cemented tungsten carbide inserts 22 are strategically affixed in circumferential rows on the roller cone 20. The size, shape and number of inserts 22 are governed by the properties of the rock being drilled. A tungsten carbide insert having a polycrystalline diamond layer on the cutting end 23, for example, is affixed on the apex 21 of the cone.

A diamond coated insert is described in detail by U.S. Patent No. 4,811,801 (see Figs. 3, 3a and 4). The patent is included in its entirety by reference. Essentially, the insert comprises a body of cemented tungsten carbide, the exposed end of which is coated with a thin layer of polycrystalline diamond.

The apex insert 23 is positioned so its axis 17 is generally not parallel with the axis 29 of cone 20 to give it a striking motion against the core 27 to induce fracture thereto (see Fig. 3). Of course, it should be understood that the insert 23 may be positioned coincident with the cone axis 29 and any off-set or

skew of the cone will impart an off-center shearing action to the insert 23, thereby drilling and maintaining the diameter of the core 27. It should be noted that, depending on the actual cone geometry and the rock formation properties anticipated, more than one diamond coated insert may be mounted in the apex of the cone. In the apexes of the other two cones (not shown) more than one diamond coated insert may be used, with the exact number being dependent on the formation properties anticipated and the specific bit design.

As can be seen in FIGURE 2, at least some of the teeth 22 in the circumferential rows around the cone extend nearer the centerline 19 of the rock bit (and hence the centerline of the borehole being drilled) than does the insert 23 in the apex of the bit. Thus, the teeth in the circumferential rows strike the central core as the cones rotate. The teeth in the circumferential rows extend a sufficient distance past the apex teeth for breaking the core. The action of these teeth fractures the central core so that the fragments can be pumped out of the borehole with the drilling fluid.

Teeth in the circumferential rows extending closer to the centerline than the apex teeth can be provided by any of a combination of design changes. The external geometry of the cone can be changed, the teeth may be made longer than usual and/or the angle that the axis of the journal makes with respect to the leg may be changed as compared with a conventional rock bit. Although the ends of the teeth in the circumferential rows may extend to the centerline, they do not need to do so to break the central core. Breaking the core with the teeth on the cones is much more effective than a core breaker as shown in U.S. Patent No. 2,901,223 or against the dome above the cones as in U.S. Patent No. 3,134,447.

FIGURE 3 illustrates a bit 10 positioned adjacent a section of the bottom portion 28 of a borehole. The bit, in this example, is designed to drill medium to hard rock formations while simultaneously cutting a core 27 with a polycrystalline diamond coated insert 23. The diameter of the core 27 is governed by the position of the apex inserts in respect to the vertical axis of drill bit. It has been determined that leaving an uncut core having a diameter greater than 10% of the gage diameter of bit, significantly increases the drilling rate and reduces the drilling cost per foot of hole drilled. The diameter of the core is defined as the largest diameter of formation left uncut at the bottom of a borehole 28 by the inserts positioned at the apex of each of the cones, the insert being closest to the hole centerline 19 at its lowest rotational position as the cone rotates on its journal 24.

Although it is desirable to leave a large core, a core greater than 25% of the bit gage diameter is extremely difficult to break up and flush from under the bit 10. This mandates that the insert(s) which cuts and trims a core to size, can not wear any significant amount without the core 27 getting to an unmanageable size. Also, if the insert 23 at the apex of the cone wears enough to allow the very abrasive core to bear on the cone and ultimately to wear through the cone, it results in failure of the cone bearing. Therefore, it is very beneficial for the core trimmer insert 23 to be essentially non-wearing diamond coated, as described above, to limit the size of the generated core and also to prevent the abrasive core from wearing through the cone shell.

In a specific example, a TCI bit having a diameter or gage of 7-7/8 inches (20 cm.) would preferably cut a core from 0.8 to 2 inches (2 to 10 cm.) in diameter for optimum bit performance in an earthen formation.

Also, limiting the size of a core allows the cone to be of normal size and wall thickness, giving room to provide a standard bearing assembly so that normal drilling parameters of drilling weight and rotary speed can be maintained in the drilling process.

When drilling certain soft, but very abrasive, earthen formations, tungsten carbide insert type roller cone drill bits, as described above, are not used because the limited extension of the cutting structure is not aggressive enough to produce an acceptable rate of penetration. Therefore, bits having long teeth milled on steel roller cones are used for this purpose. These bit types are designed to impart a large amount of drag or shear motion to the teeth, which tends to wear the steel away fairly rapidly. This is especially true close to the center or apex of the cone.

FIGURE 4 shows the lower section of a milled teeth roller cone bit generally designated as 30. The roller cone 31 is supported on a journal 36 by roller bearings 38 and ball bearings 40. Milled steel teeth 32 cooperate with teeth on the other cones (not shown) to engage the entire hole bottom except the center core 37, 10% to 25% which is left uncut. An apex cutter insert 34 is, for example, an abrasion resistant tungsten carbide insert that will last much longer than the outer steel teeth 32 even if they are coated with a hardfacing material. The steel teeth in circumferential rows away from the apex break the core. Exceptionally long teeth are not needed for breaking the core when drilling softer, less strong formations. With this arrangement, a significant increase in drilling rate is obtained, coupled with an acceptable life expectancy to effect a very desirable reduction in drilling cost per increment of hole drilled.

In certain very abrasive rocks, a diamond coated tungsten carbide apex insert may be justified. Here again, Figure 4 shows one tungsten carbide insert 34 in the apex 33 of the cone 31. It should be noted that, dependent on the particular geometry of the cone and the anticipated rock formations, there could be more than one insert in the apex. The other two cones (not shown) of the bit 30 may have inserts in or near their apexes, the exact number being determined by the cone geometry and the formation properties.

FIGURE 5 illustrates a bit 110 positioned on the bottom 128 of borehole 129. The exemplary bit is designed to drill medium to soft, non-abrasive rock formations while concurrently cutting a core 127. The bit 110 is fitted with tungsten carbide cutting inserts 122 arranged so that teeth on adjacent cones intermesh with each other. The diameter of the uncut core 127 is governed by the position of a tungsten carbide insert 122 which is located in the apex 121 of the cone. Because the anticipated rock formations are not extremely hard and are non-abrasive, tungsten carbide is sufficiently hard and wear resistant to withstand the abrasive action of cutting and maintaining the desired diameter of core 127.

With the inserts 122 in circumferential rows on the cones intermeshing, the cone has dimensions that allow a normal friction bearing 125, ball bearings 126 and carbide insert protrusion. This allows normal rotational speeds and drilling weights. Clearly, the intermeshing teeth disintegrate the core. Therefore, drilling rates are greatly increased when a core 127 is left uncut as heretofore described. Useful drilling life is at least as long as prior bits, to significantly lower the drilling cost per increment of hole drilled.

FIGURE 6 shows a bit 210 in a rotational position on the bottom 228 of a borehole 229 cutting and leaving a core 227. The exemplary bit is designed to drill soft, non-abrasive rock formations. The bit 210 has a cone with milled steel teeth 223. The cone apex 221 also has a hardfaced steel tooth 223 as the formations being drilled are very soft and non-abrasive. The steel apex tooth 223 will cut and maintain the diameter of core 227 because the apex tooth does not wear significantly to allow a grossly oversize core to develop that would be difficult to break and flush away. Significant drilling rate increases are attained with normal bit drilling life to effectively decrease the drilling cost per foot of hole drilled.

It will of course be realized that various modifications can be made in the design and operation of the present invention without departing from the spirit thereof. Thus, while the principal preferred construction and mode of operation

of the invention have been explained in what is now considered to represent its best embodiments, which have been illustrated and described, it should be understood that within the scope of the appended claims, the invention may be practiced otherwise than as specifically illustrated and described.

CLAIMS

1. A rotary cone rock bit for drilling earthen formations, the rock bit being designed to form a core while drilling a borehole for enhanced bit penetration rates, said bit comprising:

a bit body having a first threaded pin end, a second cutter end and at least a pair of legs that support roller cutter cones rotatably retained on bearings cantilevered from an end of the legs, each of the cutter cones containing circumferential rows of individual cutters;

one or more core cutter means substantially at an apex of each cone for cutting adjacent to a central core; and wherein

at least a portion of the cutters in circumferential rows extend a sufficient distance closer to the centerline of the rock bit than the core cutter means at the apex of a cone for breaking the central core.

2. A rock bit as set forth in Claim 1 wherein the distance between the core cutter means and the centerline of the bit leaves a core having a diameter in the range of 10% to 25% of the gage diameter of the bit.

3. A rock bit as set forth in either one of Claims 1 or 2 wherein each of the cutter cones contains circumferential rows of individual cutters and such a core cutter means substantially at an apex of a cone is a cutter that is harder than the cutters in the circumferential rows.

4. A rotary cone rock bit for drilling earthen formations, the rock bit being designed to form a core while drilling a borehole for enhanced bit penetration rates, said bit comprising:

a bit body having a first threaded pin end, a second cutter end and at least a pair of legs that support roller cutter cones rotatably retained on bearings cantilevered from an end of the legs, each of the cutter cones containing circumferential rows of individual cutters, the cutters on the cones being arranged for leaving a central core having a diameter in the range of 10% to 25% of the gage diameter of the bit; and

one or more core cutter means being arranged substantially at an apex of each cone for cutting the core, the core cutter means comprising a material that is harder and more abrasion resistant than the individual cutters in each of the circumferential rows of cutters on the cutter cones.

5. A rock bit as set forth in Claim 4 wherein at least a portion of the cutters in circumferential rows extend a sufficient distance closer to the centerline of the rock bit than the core cutter means at the apex of a cone for breaking the central core.

6. A rock bit as set forth in any one of the preceding claims wherein such a core cutter means is oblique to an axis formed by the cone.

7. A rock bit as set forth in any one of the preceding claims wherein such a core cutter means is oblique to an axis formed by the cone.

8. A rock bit as set forth in any one of the preceding claims wherein the individual cutters in circumferential rows are tungsten carbide inserts.

9. A rock bit as set forth in any one of the preceding claims wherein the individual cutters in circumferential rows are tungsten carbide inserts and such a core cutter means substantially at an apex of a cone is a tungsten carbide insert including a layer of polycrystalline diamond on a portion of the insert extending beyond the surface of the cone.

10. A rock bit as set forth in any one of Claims 1 through 7 wherein each of the cutter cones contain circumferential rows of individual milled tooth cutters and such a core cutter means substantially at an apex of a cone is an insert type cutter.

11. A rotary cone rock bit substantially as described herein with reference to the accompanying drawings.

Patents Act 1977
Examiner's report to the Comptroller under Section 17
(The Search report)

Relevant Technical Fields (i) UK Cl (Ed.M) E1F (FFD, FFH) (ii) Int Cl (Ed.5) E21B	Application number GB 9415788.0
	Search Examiner MR D J HARRISON
Databases (see below) (i) UK Patent Office collections of GB, EP, WO and US patent specifications. (ii)	Date of completion of Search 27 OCTOBER 1994
	Documents considered relevant following a search in respect of Claims :- 1 to 3

Categories of documents

X: Document indicating lack of novelty or of inventive step.

Y: Document indicating lack of inventive step if combined with one or more other documents of the same category.

A: Document indicating technological background and/or state of the art.

P: Document published on or after the declared priority date but before the filing date of the present application.

E: Patent document published on or after, but with priority date earlier than, the filing date of the present application.

&: Member of the same patent family; corresponding document.

Category	Identity of document and relevant passages		Relevant to claim(s)
X,P	GB 2274129 A	(SMITH INTERNATIONAL INC) 13 JULY 1994 See Figure 2, c.f. Figure 2 of present application	1
A	GB 0998323 A	(HUGHES TOOL CO)	1

Databases:The UK Patent Office database comprises classified collections of GB, EP, WO and US patent specifications as outlined periodically in the Official Journal (Patents). The on-line databases considered for search are also listed periodically in the Official Journal (Patents).